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Original Research Article

COMPUTED TOMOGRAPHY BASED PANCREATIC VOLUME MEASUREMENT IN KASHMIRI POPULATION

Gousia Nisa [1], Bashir Ahmad Shah [2], Snobar Gul [*3], Shabir Ahmad Bhat [4].

[1] Demonstrator, Department of Anatomy, Government Medical College, Srinagar, J&K, India.

[2] Associate Professor, Department of Anatomy, Government Medical College, Srinagar, J&K, India.

[*3] Demonstrator, Department of Anatomy, Government Medical College, Srinagar, J&K, India.

[4] Associate Professor, Department of Radiodiagnosis & Imaging, Government Medical College, Srinagar, J&K, India.

ABSTRACT

Background: The volume of various abdominal organs varies with age, height, weight and body mass index (BMI). Scanning of the viscera is carried out to know the normal dimensions and volumes. Studies have shown that the volume of pancreas is influenced by age, gender, ethnicity, weight, height and BMI. Organ volume and function reflect the health of the organs. Altered volume of pancreas is associated with infective, infiltrative, immunological, infestative and malignant conditions. Anthropometry varies with races and regions of the world. Specific ethnic population nomograms are needed for proper medical diagnosis and for monitoring disease progress.

Results: A total of 300 eligible subjects between 20-60 years of age, who were to undergo abdominal computed tomography (CT) due to various indications, were included in the study. In our study the mean pancreatic volume (PV) was 115.71+-33.60 cm^3. Pancreatic volume was significantly correlated with weight, height and BMI of the subjects in our study.

Conclusion: Nomograms from this data can be used locally for Kashmiri ethnic population to allow clinicians to estimate more accurately the degree of atrophy or hypertrophy of organs in certain disorders and thus, avoid false positive and false negative diagnosis of pathological enlargement or reduction of pancreas in clinical practice.

KEY WORDS: Computed tomography, Pancreatic volume, BMI.

Corresponding Author: Dr Snobar Gul, Demonstrator, Department of Anatomy, Government Medical College, Srinagar, J&K, India. **E-Mail:** snobaryounis@gmail.com

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INTRODUCTION

The dimensions of visceral organs like spleen, kidneys, liver and pancreas mentioned in anatomy books are generally the cadaveric dimensions which measure less than the dimensions of solid organs in living state. The morphology of visceral organs varies from person to person. The characteristics of abdominal organ volumes and sizes have potential clinical importance [1,2].

The volume of various abdominal organs varies with age, height and weight. Normal anatomic ranges should first be described in order to define pathological conditions and detect changes in size and volume of an organ. Computed tomography (CT) is known to be a reliable and accurate method for assessing volumes and sizes of the pancreas, spleen, kidney and other intra-abdominal organs, taking normal anatomical dimensions and

establishing diagnosis [3,4]. As the morphology differs regarding the race, therefore, a study on the pancreatic volumetry in Kashmiri subjects with no history of pancreatic diseases was undertaken. The study was conducted to assess the range of volume of normal pancreas in the adult Kashmiris using CT and to evaluate if the pancreatic volume is related to various demographic markers.

MATERIALS AND METHODS

This study was conducted in the Postgraduate Department of Anatomy in collaboration with the Department of Radiodiagnosis and Imaging of Government Medical College and associated hospitals, Srinagar for a period of eighteen months. A total of 300 eligible subjects, 20-60 years old, were included in the study. It was a cross-sectional observational type of study and proper approval from institutional ethical committee was obtained. The subjects included in this study were of Kashmiri ethnicity.

Selection of patients was done as per following inclusion and exclusion criteria:

Inclusion criteria: The in and out –patients, of either sex, who after the routine clinical evaluation, were to undergo CT examination due to various indications for the abdominal CT. Only those CT images, which were declared as 'normal' by the radiologists were included in this study.

Exclusion Criteria: Presence of either clinical or CT signs of any pancreatic or peri-pancreatic pathology, various pathological conditions affecting the adjacent organs (stomach, peritoneum or retroperitoneum) such as large tumours, fluid collections, massive lymph node enlargement with consecutive compression, infiltration or displacement of the pancreas, previous pancreatic surgery, difficult identification of pancreatic margins from the adjacent structures, history of Diabetes Mellitus, Malaria.

Contrast Enhanced CT (CECT) examination of abdomen was done using Siemens Emotion 16 Slice Multidetector Spiral CT Scan at SMHS Hospital Srinagar. The data was meticulously chosen by the radiologists. Only those CT images, which were declared as normal by the radiologists were included in this study. After identification of normal pancreas and spleen on CT scans, the following measurements (in centimetres) were taken:

· Cranial-caudal (CC) dimensions of the body (CC_{body}) and head (CC_{head}) of the pancreas. CC diameters were calculated as a product of the number of sections on which particular part of the pancreas was identified, and the section thickness.

· Anterior-posterior (AP) diameters of the tail (AP_{tail}) and body(AP_{body}) from the lineal vein to the anterior contour of the pancreatic body, and head (AP_{head}) at the level on which the pair of the superior mesenteric vein and artery is demonstrated.

· Length of body and tail ($LL_{body/tail}$) as a maximal linear distance from the pancreatic neck to the tip of the pancreatic tail.

· The pancreatic volume was computed by employing the following formula:

$$PV = (AP_{tail} + AP_{body}) / 2 \times LL_{body/tail} \times CC_{body} + (AP_{head}/2)^2 \times 3.14 \times CC_{head}$$

All statistical analyses were performed using SPSS 21.0 for Windows. Subject characteristics and results were reported as mean±SD. Correlation between organ measurements including pancreatic volume, age and BMI were studied by performing the Pearson Correlation. The strength of the correlation between organ volumes and the various parameters was considered significant at P value < 0.05

RESULTS

The mean height of female subjects was 1.524±0.817 [1.2-1.7] m and for male subjects was 1.663± 0.081[1.4-1.9] m. The overall mean height of the study population was 1.59±0.10 m (Table 1)

Table 1: Height distribution of the subjects.

Age Group	Height (m)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	1.533	0.0961		39	1.6854	0.084	
31-40	46	1.5511	0.073		25	1.6716	0.0869	
41-50	35	1.5278	0.0848	0.002	34	1.6635	0.0719	0.108
51-60	40	1.4853	0.0624		51	1.6439	0.0794	
TOTAL	151	1.5247	0.817		149	1.6639	0.0812	

The mean weight of female subjects was 59.40±13.06 [35-95] kg and for male subjects was 63.47±11.15[41-95]kg. The overall mean weight of the study population was 61.41±12.30 kg (Table 2)

Table 2: Weight distribution of the subjects.

Age Group	Weight (Kg)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	55.667	11.015		39	60.974	10.803	
31-40	46	61.826	13.255		25	66.12	9.55	
41-50	35	60.361	12.264	0.222	34	64.882	11.736	0.268
51-60	40	58.55	14.615		51	63.137	11.609	
TOTAL	151	59.401	13.064		149	63.47	11.15	

The mean BMI of female subjects was 25.42±4.90 [16.4-38.1]Kg/m^2 and for male subjects was 22.85±3.62 [14.0-32.0]Kg/m^2. The overall mean BMI of the study population was 24.15±4.49kg/m^2 (Table 3)

Table 3: BMI of subjects.

Age Group	BMI (Kg/m^2)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	23.597	3.6793		39	21.297	3.1119	
31-40	46	25.572	4.5508		25	23.644	3.0428	
41-50	35	25.714	5.1598	0.121	34	23.394	4.0132	0.018
51-60	40	26.363	5.6251		51	23.312	3.7213	
TOTAL	151	25.424	4.9029		149	22.859	3.625	

The mean craniocaudal length body of pancreas (CC_{body}) in females was 3.96±0.92 [1.3-6.4]cm and in males was 3.99±0.88[2.1-7]cm. The overall mean CC_{body} of the study population was 3.97±0.90cm (Table 4)

Table 4: Craniocaudal length body of pancreas.

Age Group	Craniocaudal Length Body Of Pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	3.943	0.9134		39	4.131	0.832	
31-40	46	4.024	0.9209		25	4.088	0.8565	
41-50	35	3.931	0.9273	0.966	34	3.806	0.8731	0.423
51-60	40	3.945	0.9716		51	3.959	0.9466	
TOTAL	151	3.965	0.9261		149	3.991	0.8856	

The mean craniocaudal length head of pancreas (CC_{head}) in females was 5.87±1.05 [3.4-9.4] cm and in males was 5.88±1.12 [2.3-9.7] cm. The overall mean CC_{head} of the study population was 5.88±1.08cm (Table 5).

Table 5: Craniocaudal length head of pancreas.

Age Group	Craniocaudal length head of pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	5.817	1.2836		39	5.831	0.9974	
31-40	46	5.893	0.9156		25	6.06	1.1456	
41-50	35	6.136	1.1494	0.25	34	5.838	1.1894	0.861
51-60	40	5.65	0.9075		51	5.914	1.1873	
TOTAL	151	5.872	1.0563		149	5.899	1.1254	

The mean anterio-posterior length tail of pancreas (AP_{tail}) in females was 2.14±0.57 [0.5-3.5] cm and in males was 2.31±0.59 [0.5-4.0] cm. The overall mean AP_{tail} of the study population was 2.23±0.57cm (Table 6)

Table 6: Antero-posterior length tail of pancreas.

Age Group	Antero-Posterior Length Tail Of Pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	2.25	0.568		39	2.485	0.4404	
31-40	46	2.3	0.5823		25	2.316	0.4845	
41-50	35	2.103	0.5321	0.009	34	2.447	0.6925	0.005
51-60	40	1.91	0.5295		51	2.088	0.6157	
TOTAL	151	2.141	0.5706		149	2.312	0.5934	

The mean anterio-posterior length body of pancreas (AP_{body}) in females was 1.79±0.46 [0.6-3.0] cm and in males was 1.94±0.52 [0.5-3.8] cm. The overall mean AP_{body} of the study population was 1.86±0.50 cm (Table 7).

Table7: Anterio-posterior length body of pancreas.

Age Group	Antero-posterior length body of pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	1.797	0.4874		39	1.915	0.5112	
31-40	46	1.863	0.4753		25	1.82	0.4848	
41-50	35	1.767	0.4864	0.719	34	2.024	0.6601	0.507
51-60	40	1.758	0.429		51	1.967	0.4633	
TOTAL	151	1.799	0.4661		149	1.942	0.5285	

The mean anterio-posterior length head of pancreas (AP_{head}) in females was 2.65±0.43 [1.6-4.1] cm and in males was 2.65±0.50 [1.5-4.0] cm. The overall mean AP_{head} of the study population was 2.65±0.47 cm (Table 8)

Table 8: Anterio-posterior length head of pancreas.

Age Group	Antero-Posterior Length Head Of Pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	2.637	0.4789		39	2.446	0.3946	
31-40	46	2.667	0.3882		25	2.584	0.5398	
41-50	35	2.653	0.4867	0.989	34	2.797	0.4815	0.005
51-60	40	2.64	0.4325		51	2.767	0.5203	
TOTAL	151	2.651	0.4385		149	2.659	0.5016	

The mean lateral-lateral length body-tail of pancreas ($LL_{body-tail}$) in females was 9.82±1.48 [5.1-13.2] cm and in males was 10.42±1.53 [6.4-14.6] cm. The overall mean $LL_{body-tail}$ of the study population was 10.11±1.53cm (Table 9).

Table 9: Lateral-lateral length body-tail of pancreas.

Age Group	LL Length Body-Tail Of Pancreas (cm)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	9.593	1.5827		39	9.779	1.3385	
31-40	46	9.765	1.3188		25	10.436	1.6904	
41-50	35	9.858	1.4009	0.658	34	10.412	1.2475	0.007
51-60	40	10.035	1.6759		51	10.908	1.6342	
TOTAL	151	9.824	1.4844		149	10.42	1.5372	

The mean pancreatic volume (PV) in females was 110.20±32.80 [40.70-193.31] cm^3 which was less than males 121.18±33.73 [56.57-207.60] cm^3. The overall mean PV of the study population was 115.71±33.60cm^3. (Table 10)

Table 10: Pancreatic volume.

Age Group	Pancreatic volume (cm^3)							
	Females			P Value	Males			P Value
	N	Mean	SD		N	Mean	SD	
20-30	30	107.67	27.79	0.521	39	116.22	28.91	0.732
31-40	46	114.57	32.67		25	120.64	37.62	
41-50	35	112.68	37.9		34	124.11	34.15	
51-60	40	104.82	31.75		51	123.28	35.41	
TOTAL	151	110.2	32.8		149	121.18	33.73	

Mean pancreatic volume was higher in males than in females in our study population and the difference was statistically significant ($p<0.05$) for pancreatic volume (Table11)

Table 11: Comparison of pancreatic volume in male and female subjects.

Parameter	Sex	MEAN ± SD	t-statistic	df	P value
Pancreatic volume	Male	121.18 ± 33.73	2.864	299	*0.004
	Female	110.20 ±32.80			

All the parameters used, except age, showed positive correlation with pancreatic volume which was statistically significant ($P<0.05$). Age also showed positive correlation but was statistically insignificant ($P>0.05$)(Table12).

Table 12: Relationship between parameters used and pancreatic volume.

Correlation With Pancreatic Volume				
Parameter	Mean	SD	Pearson coefficient	P Value
Age	43.236	12.7601	0.014	0.804
Height	1.5936	0.1071	0.266	**0**
Weight	61.415	12.3038	0.369	**0**
BMI	24.154	4.498	0.196	**0.001**

DISCUSSION

The characteristics of abdominal organ volumes and sizes have potential clinical significance. A change in volume of an organ is often either the predominant feature of a disease process or a secondary manifestation of pathology elsewhere e.g. pancreatic atrophy is associated with changes in exocrine functions [5,6]. While the pancreatic neoplasm and the acute pancreatitis usually cause the focal or generalized enlargement of the pancreas, the chronic pancreatitis leads to decrease of pancreatic size and volume [7,8]. In addition, reduction in the pancreatic volume in diabetic patients has been reported [9,10-13]. The volume of various abdominal organs varies with age, height and weight. Studies report increased pancreatic echogenecity with aging, suggesting the age-related fat accumulation and decline in glandular tissue in the pancreas [14].

Pancreatic size is a key parameter that is used in the experimental setting to assess pancreatic growth, development and recovery following injury [15,16]. Pancreatic volume is very important in the evaluation of Protein Energy Malnutrition patients and can be used as a predictive parameter and any change in pancreatic volume may affect its function [17]. The volume of the pancreas increases with obesity and there is a relationship between BMI and pancreatic volume assessed by CT [9]. The use of CT imaging is receiving increasing attention to estimate pancreatic volume [6,18].. In vivo volume calculation of tumours also has clinical potential in radiation oncology. Due to precise definition of organ and tumour contours with cross-sectional CT and the ease of scanning these structures in their entirety, CT potentially offers the most accurate non-invasive means of estimating in vivo volumes [19].

The variation in the anthropometric features of various populations, races and regions is an established fact. In contrast to many previous studies which were mainly done on the foreign population, our data was obtained from subjects of Kashmiri ethnicity.

Our study comprised of 300 subjects between 20 and 60 years of age with 23.0% between 20 to 30 years, 23.6% between 31 and 40 years, 23.0% between 41 and 50 years and 30.3% between 51-60 years of age. Majority of the subjects were in the age group of 51-60years. As most of the visceral organs reach the adult size by the age of 18 years, pancreatic volume reaches a plateau from 20-60 years and then declines thereafter, so this age group was taken up for the study. The mean age was 43.32 years in total series. The mean age was more in other studies (Djuveric A [2], Caglar V [1,20]) due to the fact that in our study subjects of 20-60years only were included, while as in their studies older subjects were also included. However,

there was no statistically significant difference between the mean ages of males and females, hence, these two groups were comparable. Our study group had 149(49.6%) males and 151(50.3%) females. Caglar V et al [20,21] and Djuric-Stefanovic A et al [2] found that there were 136(50.0%) males and 136(50.0%) females; 107(50.4%) males and 105(49.5%) females; 118(53.6%) males and 102(46.3%) females respectively, in their studies with almost equal sex ratio as in our study.

The mean weight of our study group was 61.41kgs with minimum 35kgs and maximum 95kgs. The mean height was 1.59m with minimum height 1.20m and maximum height 1.85m. The mean BMI was 24.15kg/m^2 with minimum BMI 14.0kg/m^2 and maximum 38.1kg/m^2.

The mean PV for the total study population of 300 subjects was 115.71±33.60cm^3. A wide range of the PV values from 40.73 to 207.60cm^3 was observed in our study. In the first reported computed tomography based PV calculation series of 41 pancreases a value of 40.4±9.3cm^3 was reported by Von Schulz HG et al [22] 1986 which is almost thrice as less as in our study. Small sample size, older generation of CT equipment and possible demographic variations may be reason for such difference. Geraghty et al [5] 2004 reported that the mean PV in their CT based series of 113 individuals was 64.4±18.1cm^3 and 87.4±21.3cm^3 for females and males, respectively, with a range from 22.4 to 136.6cm^3. The latest available study of Saisho et al [9] 2007 with the largest series of 1721 adult individuals, reported the mean PV of 72.4±25.8cm^3 (85.2±26.9cm^3 and 63.0±20.5cm^3 for male and female groups respectively). These values are moderately less than those reported in our study. Williams et al [24] 2007 reported an average PV of 101±19.5cm^3 which is quite similar to our study. The differences might be explained due to differences of the number, mean age and gender of the individuals enrolled in the study and regional differences between populations. We think that autopsy studies are insufficient to explain the relation between PV and age because of small number of cases, lack of classification of age groups and absence of clinical history with regard to pancreatic pathologies. The pancreatic volume changed little during 20-60 years of age in our study, which was compatible with the values reported in the literature [3,23]. In our study the volume of the pancreas did not significantly correlate with age ($r = 0.014$, $p = 0.804$). Saisho et al [9] found that the volume of the pancreas was not age-dependent within 20-60 years, yet in older individuals the PV gradually decreased as age increased. Djuveric A et al[3] and Caglar V et al [23,37] also did not find statistically significant correlation between the volume of the pancreas and the age of the individuals. The average pancreatic volume was significantly higher in males (121.18±33.73cm^3) than in females (110.20±32.80cm^3) ($t = 2.864$, $df = 299$, $p = 0.004$) in our study. Our results are very similar to those in literature [3,5,9,23,28]. Such correlation probably resulted from the anthropometric variations between males and females.

Organ volume is usually associated with weight and height [28]. We found a significant correlation between pancreas volume and weight($r = 0.369$, $p = 0.000$), height($r = 0.266$, $p = 0.000$) and BMI($r = 0.196$, $p = 0.001$). Sheikhazadi et al[20] 2010 reported a correlation between PV and BMI only in women. Other studies demonstrating the relationship between PV and weight, height and BMI are also available [9,11-13,23,27,29]. The presence of a significant relationship between PV and BMI suggests an effect of obesity on the pancreatic volume. The fact that PV is greater in obese persons may be due to an increase in the pancreatic fat rather than an increase in the pancreatic parenchyma [9]. This is further supported by the study of De La Grandmaison et al [28] 2001 who reported that the degree of pancreatic lipomatosis was significantly associated with age and overweight. This condition is more compatible with the prevelance of diabetes in obese people.

Pancreatic volume positively and strongly correlated ($p = 0.000$) with all the diameters of the pancreas that were measured by CT imaging. All measured diameters of the pancreas were longer in males than in females. Similar results were reported by Djuveric A et al [3]. The potential limitations of this study include that the data cannot be generalized as this study included only subjects from an ethnic

population, but our study was designed to formulate the data for this population only.

CONCLUSION

In conclusion, this study was conducted to establish a local reference of values for the pancreatic volume of the Kashmiri adult population. Nomograms from this data can be used locally for Kashmiri ethnic population to allow clinicians to estimate more accurately the degree of atrophy or hypertrophy of organs in certain disorders and thus, avoid false positive and false negative diagnosis of pathological enlargement or reduction of spleen in clinical practice.

Conflicts of Interests: None

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